

sea pac 2001
technical workshop

Debugging antennae

by Marshall Johnson, Sr. - KK7CW

Amateur Antenna Supply

-a division of Pacific-Evergreen Communications, Albany, Oregon

Email: kk7cw@proaxis.com

AN OVERVIEW:

AN ANTENNA is an electro-mechanical device used for the purpose of transferring electrical energy to and from a radio through the ether.

Resistor, inductor, capacitor

AN ANTENNA is an electronic circuit capable of transferring radio frequency energy.

AN ANTENNA is capable of transmitting and receiving.

AN ANTENNA has components that react in a repeatable, predictable and measure-able manner.

AN ANTENNA, of proper design, is an efficient device or tool.

AN ANTENNA uses the surface of the earth and the earth's atmosphere as operational components.

AN ANTENNA is subject to its environment.

AN ANTENNA is used for communication.

Radio wave propagation, and its associated study, is an art supported by decades of scientific data, mathematical calculation and computer modeling.

Antennas can vary in performance with changes in frequency of excitation, environmental conditions, conductive material, dimension and quality of circuit design.

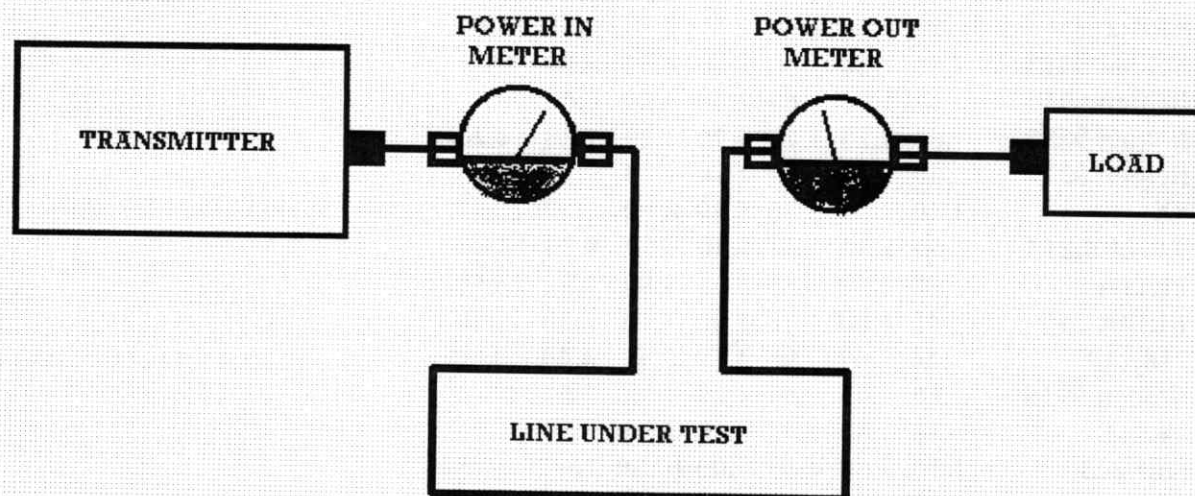
Antenna systems consist of matching devices, switching devices, feedlines, ground systems, radiators, environmental coping devices and support structures.

TERMS:

- **Radiation Resistance:** The ratio of the power radiated by an antenna to the square of the RMS antenna current, referred to a specific point. The effective load resistance of the antenna feedpoint. Measured radiation resistance, (R_a) is comprised of a combination of radiation resistance (R_r), ohmic loss resistance (R_i) and dielectric loss (R_d). $R_a = R_r + R_i + R_d$ $R_r = I \times I \times R$ losses.
- **Impedance (Z):** The ohmic value of the antenna feedpoint, matching section or transmission line. Impedance is the total of all component, resistive (R) and reactive, values (XC or XL). $Z^2 = R^2 + X^2$ (capacitive or inductive)
- **Characteristic impedance (K):** is the measured or stated value of a radiator, matching section or transmission line consisting of resistance and reactance.
- **Resonance:** the characteristic of a tuned circuit of a characteristic impedance, where the reactance value is "0j" and the resistance value is at minimum. $R_{es} = R_{min} + 0j$
(Not necessarily 50 ohms)
- **Natural resonance:** a half wavelength of wire or multiples thereof, a quarter-wavelength radiator and counterpoise exhibiting no reactance. An end-fed half-wave wire antenna exhibits natural resonance.
- **Efficiency:** the ratio of useful output power to input power, determined in the antenna systems by losses in the system, including ground, nearby objects (dielectric loss) and ohmic loss.
$$\frac{R_r}{R_a} \times 100 = \text{efficiency \%}$$
- **VSWR or SWR:** is the voltage standing wave ratio on a transmission line in an antenna system. The ratio of the forward to reflected voltage on the line, and not a power ratio. A vswr of 1:1 occurs when all parts of the antenna system are matched correctly to one another.

- **Velocity Factor:** is the ratio of the velocity of radio wave propagation in a dielectric medium to that in free space. When cutting a transmission line to specific electrical length, the velocity factor of the particular line must be taken into account. RG-8 may have a velocity factor of .66. To predetermine half-wave of RG-8, multiply 492 times .66, then divide by the frequency of interest. The length will be determined in feet and is an approximation dependent on the cable manufacturer.
- **Angle of Departure:** is the angle relative upward from the horizon to the center of the main radiation lobe of the antenna. Angles of departure less than 30 degrees are generally accepted as good for DX contacts. Angles above 60 degrees are considered good for contacts of less than 500 miles (NVIS). Near-field ground losses can substantially impact an antenna systems angle of departure.

FEEDLINE EFFICIENCY



$$\frac{\text{Power Out}}{\text{Power In}} = \text{Efficiency \%}$$

FEEDLINE INFORMATION:

TRANSMISSION LINE LOSS TABLE FOR COAXIAL LINE

(all values are DB per 100 feet)

Cable type RG/U	Frequency in MHZ						
	10	50	100	200	400	1000	3000
6A	.04	1.90	2.70	4.10	5.90	9.80	23.00
8,8A,213	.55	1.30	1.90	2.70	4.10	8.00	16.00
Belden 9913	**	.64	1.00	1.60	2.50	4.50	**
Belden 9914	**	1.10	1.60	2.40	3.50	6.00	**
Belden 9888	.60	1.20	1.70	2.70	4.20	7.80	14.20
Belden 8214	.60	1.20	1.70	2.70	4.20	7.70	14.20
8X	1.10	2.50	3.70	5.40	8.00	13.50	26.00
9,9A,9B,214	.66	1.50	2.30	3.30	5.00	8.80	18.00
11,11A	.66	1.60	2.30	3.30	4.80	7.80	16.50
14,14A,217	.41	1.00	1.40	2.00	3.10	5.50	12.40
218,219	.24	.62	.95	1.50	2.40	4.40	9.50
Belden 9915	**	.60	.80	1.20	1.90	3.50	**
34,34B	.32	.85	1.40	2.10	3.30	5.80	16.00
55B,223	1.20	3.20	4.80	7.00	10.00	16.50	30.50
58	1.25	3.15	4.60	6.90	10.50	17.50	37.50
58A,58C	1.40	3.30	4.90	7.40	12.00	24.00	54.00
59,59B	1.10	2.40	3.40	4.90	7.00	12.00	26.50
62,62A	.85	1.90	2.70	3.80	5.30	8.70	18.50

** -- No data available

Characteristics of Commonly Used Coax

RG/	Ohms	VF%	Dielectric Max			
			PF	OD	Material	Volts
6	75	75	18.6	.266	FPE	1000
8x	52	75	26.0	.242	FPE	800
8	52	66	29.5	.405	PE	4000
8M	52	80	25.4	.405	FPE	1500
8A	52	66	29.5	.405	PE	5000
9,9A	51	66	30.0	.420	PE	4000
9B	50	66	30.8	.420	PE	5000
11	75	66	20.6	.405	PE	4000

(CONTINUED)

11 Foam	75	20.6	.405	FPE	1600
11A 75	66	20.6	.405	PE	5000
12 75	66	20.6	.475	PE	4000
12A 75	66	20.6	.475	PE	5000
17,17A52	66	29.5	.870	PE	11000
55,55B53.5	66	28.5	.216	PE	1900
55A 50	66	30.8	.216	PE	1900
58,A,B53.5	66	28.5	.195	PE	1900
58 Foam	53.5	28.5	.195	FPE	600
58C 50	66	30.8	.195	PE	1900
59 73	66	21.0	.242	PE	2300
59 Foam	75	16.9	.242	FPE	800
62,A,B93	86	13.5	.242	A/PE	750
62 Foam 95	79	13.4	.242	FPE	700
133A 95	66	16.2	.405	PE	4000
141,A 50	70	29.4	.190	PTFE	1900
142,A 50	70	29.4	.206	PTFE	1900
142B 50	70	29.4	.195	PTFE	1900
174 50	66	30.8	.100	PE	1500
213 50	66	30.8	.405	PE	5000
214*215 50	66	30.8	.425	PE	5000
216 75	66	20.6	.425	PE	5000
223* 50	66	30.8	.212	PE	1900
9913* 50	84	24.0	.405	A/PE	750
9914* 50	78	26.0	.405	FPE	700

* DOUBLE SHIELD

FPE=Foam PE A/PE=Air/PE

Aluminum Jacket Foam

INCH

1/2	50	81	25.0	.500	2500
3/4	50	81	25.0	.750	4000
7/8	50	81	25.0	.875	4500
1/2	75	81	16.7	.500	2500
3/4	75	81	16.7	.750	3500
7/8	75	81	16.7	.875	4000

(CONTINUED)

Parallel Line

OPEN/LONG WIRE	-	-	-	-
----------------	---	---	---	---

75 T/L	75	67	19.0	-	-	-
300 T/L	300	82	5.8	-	-	-
300Tube	300	80	4.6	-	-	-

OPEN WIRE TV TYPE

1/2	300	95	-	-	-	-
1 INCH	450	95	-	-	-	-

Dielectric	Name	Temperature Limits
PE	Polyethylene	-65 to +80c
Foam PE	Foamed Polyethylene	-65 to +80c
PTFE	Teflon	-250 to +250c

By - KK7CW - M. D. Johnson, Sr.

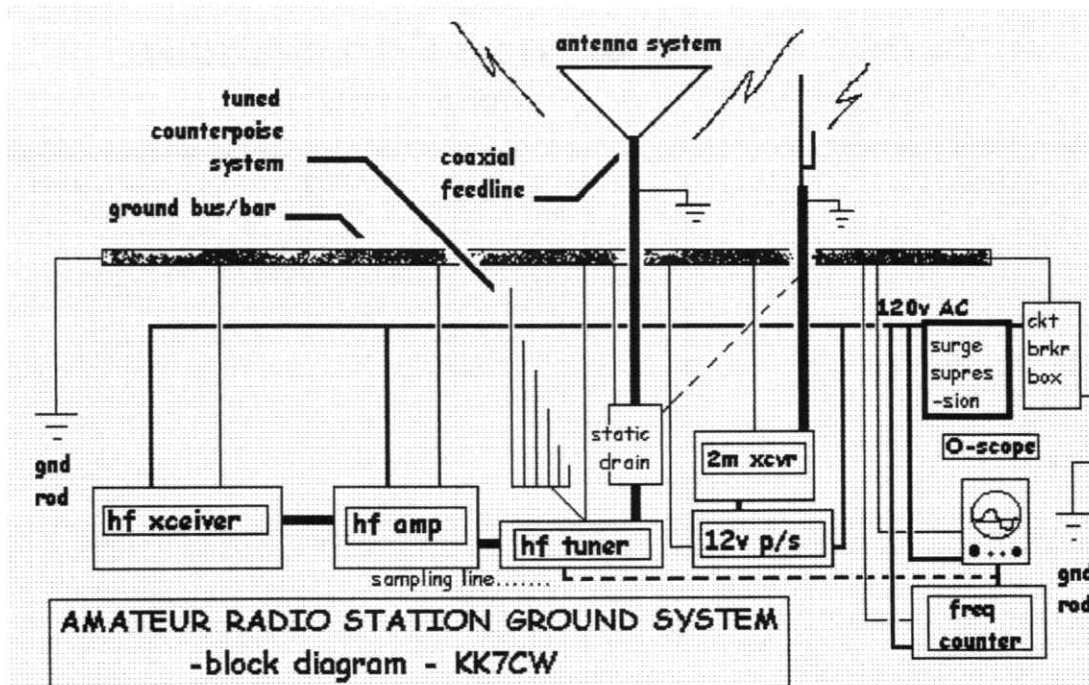
Antenna Performance Comparison

compiled by Ed Van Overloop - WA2UGT

Antenna Type @ 40 feet	Ground Wave	Short Skip	Long Skip	Short Term Fade
80m Skyfighter	fair	excellent	good-excell.	very good
Double Zepp	poor	very good	fair-good	poor
80m TT Marconi	good	good	fair	good
Carolina Windom	fair	very good	fair	poor
Multi Trap Dipole	poor	very good	fair	poor
G5RV	poor	good	poor	poor
2-El Multi Quad	very good	good	excellent	very good
Trap Triband Yagi	good	fair	good-excell.	fair
Half Wave Vert.	excellent	fair-good	good	poor

Note: Skyfighter is full-wave horizontal loop, TT Marconi is tv-twinlead inverted "L", Multi is multi-band radiator, Carolina Windom is an (OCF) off-center-fed dipole and Double Zepp is center fed double extended .64 wavelength radiator, G5RV is 102 ft. dipole with tuned parallel feed line (named after Louis Varney).

Prepared by Aerials International - KK7CW - M. D. Johnson, Sr.



GOOD GROUNDING BEGINS AT THE STATION FOUNDATION
by KK7CW - Marshall Johnson, Sr.

Good station grounding allows amateur radio operators safety and enhanced operating characteristics for the station's communications equipment. A ham station ground system should fall in four basic categories. They include: 1) an electrical ground (AC/DC), 2) a radio frequency ground (tuned counterpoise), 3) a lightning or static dissipation ground and 4) an electromagnetic pulse ground (EMP). The ideal situation is to combine all four of the basic systems in your station.

A good electrical ground is probably the best understood of all ground systems. The third pin on the power supply wall plug is an electrical ground. However, the ground lug on the back of your transceiver, dc power supply, antenna tuner, amplifier and such is also part of the stations electrical ground system. All of your station equipment should have a common ground to your stations earth ground, the ground for your stations wall current and/or the buildings circuit breaker box. Remember, any resistance between any two pieces of electronic equipment produces a voltage potential. Voltage potential means there is not a

sufficient or proper ground. All station grounds should directly terminate at the same point with resistance from each piece of equipment to the common termination as close to zero as possible. This is known as a "star" ground system.

The most forgotten part of a complete station ground system is the radio frequency ground system or "the tuned counterpoise system". Many ham radio operators have discovered that tvf and rfi problems nearly disappear with the addition of a good tuned rf ground system. Most often the quarter wave length tuned ground wires are connected at the tuner or final power amplifier grounding lug. The same formula for configuring a quarter-wave vertical is sufficient for calculating the length of each counterpoise wire for each band you transmit on. Many operators report lower receiver noise figures and increased sensitivity with the addition of a tuned rf ground system.

Static electricity is often overlooked as the culprit for noise reception and, possibly, receiver front end destruction. Lightning is the most visible destroyer of ham radio equipment. Rf rectification between oxidized metal surfaces can store static charges. Static electricity created by wind passing over antenna surfaces can, at times, build up a charge of several hundred volts at several hundred milliamps. One static discharge can completely disable your transceiver (hf, 2m, 70cm, ect.). The use of a gas discharge device or spark gap between your antennas and your station transceivers is an excellent investment.

And finally, the least known of all ground systems. The electromagnetic pulse or "EMP" system on your station will add years to the life of your station. All electrical power supplied to your station possesses electromagnetic pulses capable of weakening or destroying any solid state electronic device. In addition, during a severe wind storm, it is common for power lines to swing back and forth violently causing the common/neutral wires to come in contact with the "hot" leads causing power to actually flow backwards into your station through the building electrical ground. Metal oxide varistors (mov's) and medium power zener diode devices provide protection from emp. The protection device takes the brunt of the emp and is destroyed instead of your station's equipment. Ground fault interruptors (gfi's) have also provided some measure of protection from harmful emp.

A complete and safe ground system for your station will require planning. So take the time to add years of life and enjoyment to the great hobby of amateur radio.

Radio Frequency Radiation Safety –

As of January 1, 1998, the F.C.C. requires amateur radio licensees to be aware of the hazards of radio frequency radiation. Scientists, after decades of study, have determined what are the safe levels of human exposure. A helpful supplement, just for amateur radio, was developed by the F.C.C.. An article by Ed Hare, K1RFI, outlines how hams can easily comply with the new standards.

<<http://www.arrl.org/news/rfsafety/eval>>

RF Awareness Guidelines – General Safety

These guidelines were developed by the ARRL RF Safety Committee, based on the FCC/EPA measurements.

Although antennas on towers (well away from people) pose no exposure problem, make certain that the RF radiation is confined to the antennas' radiating elements themselves. Provide a single, good station ground (earth), and eliminate radiation from transmission lines. Use good coaxial cable, not open-wire lines or end-fed antennas that come directly into the transmitter area.

No person should ever be near any transmitting antenna while it is in use. This is especially true for mobile or ground-mounted vertical antennas. Avoid transmitting with more than 25 W in a VHF mobile installation unless it is possible to first measure the RF fields inside the vehicle. At the 1-kW level, both HF and VHF directional antennas should be at least 35 ft above inhabited areas. Avoid using indoor and attic-mounted antennas if at all possible.

Don't operate high-power amplifiers with the covers removed, especially at VHF/UHF.

In the UHF/SHF region, never look into the open end of an activated length of waveguide or point it toward anyone. Never point a high-gain, narrow-bandwidth antenna (a paraboloid, for instance) toward people. Use caution in aiming an EME (moonbounce) array toward the horizon; EME arrays may deliver an effective radiated power of 250,000 W or more.

With hand-held transceivers, keep the antenna away from your head and use the lowest power possible to maintain communications. Use a separate microphone and hold the rig as far away from you as possible.

Don't work on antennas that have RF power applied.

Don't stand or sit close to a power supply or linear amplifier when the ac power is turned on. Stay at least 24 inches away from power transformers, electrical fans and other sources of high-level 60-Hz magnetic fields.

Copyright © 1998, American Radio Relay League, Inc. All Rights Reserved. KK7CW

FORMULAS

1. free-space one wave length (meters) = $\frac{299,800,000}{f/\text{hertz}}$

2. half wave length/free space (feet) = $\frac{491.8}{f/\text{mhz}}$

3. half wave length/wire (feet) = $\frac{468}{f/\text{mhz}}$

4. half wave length/wire (inches) = $\frac{5902}{f/\text{mhz}}$

5. 1/4 wave length/wire (feet) = $\frac{234}{f/\text{mhz}}$

6. impedance $Z^2 = R^2 + X^2$
 R = resistance
 X = reactance

7. inductive reactance (solve for ohms)
 $XL = 2 \times 3.14 \times \text{freq} \times L$

8. capacitive reactance (solve for ohms)
 $XC = \frac{1}{2 \times 3.14 \times \text{freq} \times C}$

9. resonant frequency = $\frac{1}{2 \times 3.14 \times \sqrt{L \times C}}$

10. eletrical tuned feedline length:

1/4 wave/tuned = $\frac{246 \times Vf}{f/\text{mhz}}$ Vf = velocity factor (can be found in ARRL ANTENNA BOOK)

1/2 wave/tuned = $\frac{492 \times Vf}{f/\text{mhz}}$

11. series 1/4 wave coaxial transformer:

$Z_i = \frac{Z_o^2}{Z_l}$ or $Z_o = \sqrt{Z_i \times Z_l}$
 Z_i = input impedance
 Z_o = line characteristic impedance
 Z_l = load impedance

12. full wave loop/skywire = $\frac{1005}{f/\text{mhz}}$

13. SWR = $\frac{Z_o}{R}$ or $\frac{R}{Z_o}$

Z_o = line/source impedance
 R = load resistance (complex lump impedance can be substituted)

14. maximum line current = $\frac{E_{\text{max}}}{Z_o}$

15. maximum line voltage = $\sqrt{P \times Z_o \times \text{SWR}}$

16. power in watts radiated from antenna = $I^2 \times R_{\text{rad}}$

DEBUGGING PLAN: PROBLEM AREAS

TEST MEASUREMENTS:

*Test Controls:

calibration

known environment

documentation

methodology

repeatable & predictable/expected results

*Height Above Ground

*Resonance Min. Impedance = Resonance

*VSWR at desired frequency

*2:1 Bandwidth

MECHANICAL:

*Check dimensions – (-do they match the mfg. documentation.)

*Maintenance

joints

oxguard > ANTI-oxidant
No ox

connections

cracking, broken conductors

stressing – torsion, sheer, wind-load

corrosion

*Element taper

*Element location

*Span/Inertia/Gravity

*Material used

mystery oil

*Length:Diameter Ratio

*Moisture protection

No coax seal
Bearing Co. - Dow Corning High Vacuum silicon
Dielectric Grease

PROXIMITY:

*Distance to:

- ground
- structures – tower, roof, gutter, mast, light poles, metal buildings
- vehicles
- utility lines
- other antennas
- trees, vegetation

*Orientation

*Any conductive object with $\frac{1}{4}$ wave length will cause a change in the tuning and performance of an antenna.

FEED SYSTEM:

*Proper line for the use (RG-213, RG-8, RG-8/U, ect.)

*Age of feedline

*Typical problems:

- moisture
- oxidation/corrosion
- dielectric migration
- animals/birds/insects
- moss/mold
- ultraviolet radiation
- dust/dirt
- chemicals/grease/sealants
- overheating
- soldering

*Check each and every component of the system separately and all together.

*Feedline routing

YE OLDE VOO-DOO

*Antennas work best at 50 ohms.

*Antennas must exhibit 1:1 VSWR.

*Once an antenna is installed, it will stay that way permanently.

*My antenna makes contacts, so it must be O.K.

*Antenna efficiency is greatly over-stated.

*My antenna has more gain than yours does, therefore I can talk farther.

*Antenna patterns are less important than gain.

*Age of the antenna+age of the transmitter+age of the operator=superior signal

THE PROCESS: DUBUGGING

BY KK7CW – MARSHALL JOHNSON, SR.

- I. Antennas are “electronic circuits” made up of common electronic components that act in predictable ways when radio frequency energy is applied. Antennas are also mechanical devices subject to their environment including weather, gravity and misuse.**
- II. When analyzing an antenna system, planning your steps and documenting your results are some of the most important elements of success.**
- III. Basic Steps.**
 - 1. Gathering data, test measurements, accuracy, duplicating results. Use more than a VSWR meter. Analyzers, impedance meters, RF bridges, field strength meters, dip meters and wave absorption meters can provide valuable data in helping you solve antenna problems.**
 - 2. Mechanical aspects of system are consistent with proper design (-did you follow the dimensions in the assembly instructions “exactly”). With “tapered”**

elements, have tapering effects been properly calculated. Has the size of the element been taken into consideration?

3. Determine the effects of the antenna's surroundings, "proximity effect". Many antenna builders forget height above ground can change your antenna.

4. Feed systems and matching systems properly constructed and tested.

5. When all else fails, "ask for help". The person who will help you the most is the one who begins by asking you questions first and leaves the suggested solution(s) until last. REMEMBER, analyze the feed system first, then the electronic circuit, next is mechanical and finally the environmental/proximity concerns.

IV. Do the easiest and simplest corrections first...and do them ONE AT A TIME. Your purpose is to get the antenna to work and LEARN something in the process. It is not important to understand everything about the correction process before you begin. Just proceed with caution and a plan.

- V. When designing or correcting a “home-brew” antenna system, use the same basic steps. Keep track of the steps taken in the development of your antenna design. Document what works and what doesn’t. When you discover a problem, correcting it will be much easier. Plus, when you do ask for help, your Elmer can apply what he knows to your situation much more easily.**

TEST MEASUREMENTS:

ANTENNA TYPE: _____

MANUFACTURER: _____

DATE OF INSTALLATION: _____

DATE OF TEST: _____

CALL SIGN: _____

RESONANT FREQUENCY: _____ MHz.

VSWR: _____

2:1 BANDWIDTH: (UPPER) _____ (LOWER) _____

RESISTANCE: _____ OHMS AT RESONANT FREQUENCY.

+20 KHz: _____

-20KHz: _____

REACTANCE AT DESIRED FREQUENCY: _____ +/-J FACTOR.

FEEDLINE: (TYPE) _____ (IMPEDANCE) _____ OHMS.

TEST RESULTS: _____

NOTE: remember, remove all tuning, switching and connected devices from feedline prior to testing.

DEBUGGING PLAN/PROCESS:

DEBUGGING ANTENNAE

ANSWER SHEET

1.

2.

3.

4.

5.

6.

ANSWER SHEET – PG 2

7.

8.

9.

10.